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THE SANITARY CLASSIFICATION OF STREAM WATERS IN CONNECTION WITH POLLUTION ABATEMENT PROGRAMS

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The Sanitary Classification of Stream Waters in Connection with Pollution Abatement Programs.

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In undertaking any systematic program of stream pollution abatement, it is necessary first of all to obtain accurate information as to the sanitary condition of the streams located in the particular area concerned. This information is essential both in order to show where corrective measures may be necessary and to estimate the extent of these measures which may be required in each stream or stream zone.

Although field surveys of sources of pollution afford highly essential data as a basis for applying corrective measures, and also provide a valuable means of checking observed conditions of pollution in streams, the most direct method of ascertaining these conditions is the examination of the streams themselves by laboratory methods, which have become well-established through past experience. It is the purpose of this paper to discuss the particular kinds of laboratory data which have been found to be best adapted to the more practical ends of stream pollution surveys and also to present a suggested general scheme for classifying streams on the basis of their measurable pollution and their general fitness for more common uses.

Laboratory Measures of Pollution and Self-purification.

During recent years, the older laboratory measures of stream pollution and natural purification, such as permanganate consumed and nitrogen in its various states of oxidation, have been quite generally replaced by simpler and more direct indicators, such as (1) the coliform group of bacteria, (2) dissolved oxygen content and (3) 5-day biochemical oxygen demand(B.O.D.). These three tests may be said, in fact, to provide a reliable and fairly complete means

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of judging as to the sanitary condition of a stream, both immediately below sources of pollution and at more remote points downstream, after dilution and natural purification have become effective.

Under some conditions, other laboratory tests, such as those for turbidity, alkalinity or acidity, pH value and volatile solids have a definite special value. Of more general significance is the biological examination of stream waters, which often yields extremely valuable information as to the status of pollution of a natural watercourse. The water biologist is now in a position to identify and enumerate certain plankton which are reliable indicators of clean or of polluted waters. A study of the relative proportions of these "index organisms" often affords a definite clue of conditions which may represent the cumulative effects of pollution even where other tests may give temporarily a contrary indication. Moreover, the biological findings may reveal food conditions favorable or unfavorable to fish and other higher aquatic life far more definitely than can be shown by any other method.

Classification of Stream Waters.

Experience and observation in water pollution and its effects on various water uses have suggested certain limiting requirements for these uses which may be expressed quite definitely in terms of laboratory indicators of pollution. For example, extensive studies by the Public Health Service[1] have established reasonably safe limits of pollution, in terms of coliform bacteria, for raw waters taken for treatment to various degrees. Lower limits of dissolved oxygen compatible with maintaining different varieties of fish life have been studied by the Bureau of Fisheries[2] and others[4].

After reviewing all of the available sources of scientific information at hand, the present writer has endeavored to set down a general classification scheme for stream waters, based on limiting requirements of quality expressed

in terms of more common measures of pollution. The primary requirements of this classification are based on the three aforesaid measures of pollution, namely; (1) the coliform bacterial number, (2) the dissolved oxygen content, and (3) the 5-day biochemical oxygen demand. All of these measures are based on standard laboratory procedures well-known among sanitary laboratory technicians. Certain added requirements, also based on standard laboratory tests, have been included in the classification scheme, in order to embrace certain conditions which are not fully comprehended by the three primary measures above noted.

The classification described has been used in the analysis of extensive laboratory data obtained in connection with the Ohio River Pollution Survey during the year 1939. It has been subjected to thorough review and criticism by various members of the technical staff of the Survey and its original provisions have been modified wherever agreement has been general that any change should be made. The classification has been useful in forming a systematic judgment as to the sanitary status of various streams, or stream zones, and accordingly as to the extent of corrective measures needed in specific cases.

For purposes of the classification scheme, stream waters have been divided into three classes, designated as "A", "B" and "C". A special class, "AA", has been included also, in order to cover sanitary requirements of an exceptionally high order for water uses such as bathing, sport fishing and reserved recreational areas. This special class does not, however, form an integral part of the general scheme.

The requirements for Class A have been drawn so as to provide desirable conditions in streams for normal uses and to maintain a high degree of biological equilibrium necessary to supporting natural purification. Class B represents conditions which though tolerable in some respects are undesirable

for first class streams. Class C is definitely unsatisfactory, marking conditions which are virtually intolerable for any normal stream use except the disposal of wastes.

The requirements drawn for each class are intended to be applied with entire flexibility, so far as predominant water uses are concerned. For example, in streams or stream zones not used, nor expected to be used, as sources of water supply, but in which other uses, such as recreational, are involved, the limiting requirement with respect to coliform bacteria could be waived in favor of the dissolved oxygen and B.O.D. requirement wherever these general requirements were in conflict with each other.

A condensed statement of the primary requirements for each class, together with an amplified statement of the complete standards, are given below. These statements are followed by explanatory notes giving the basis of the requirements.

I. Primary Requirements.

(1) Coliform Numbers

Class A - Average not over 5,000 per 100 ml. in any month.

Class B - Average over 5,000 per 100 ml. but not over 20,000 in any month.

Class C - Average over 20,000 per 100 ml. in any month.

(2) Dissolved Oxygen

Class A - Average not less than 6.5 p.p.m. in any month.

Class B - Average not less than 5.0 p.p.m. in any month.

Class C - Average less than 5.0 p.p.m. in any month.

(3) 5-Day B.O.D.

Class A - Average not more than 3 p.p.m. in any month, and at least 3 p.p.m. less than the dissolved oxygen content.

Class B - Average not more than 4 p.p.m. in any month.

Class C - The 5-Day B.O.D. averages more than 4 p.p.m. in any month.

II. Complete Requirements.

Class A

(1) The number of coliform bacteria should average not more than 5,000 per 100 ml. in any month.

(2) The dissolved oxygen content should average not less than 6.5 ppm in any month and not less than 5 p.p.m. on any day.

(3) The 5-Day B.O.D. should average in any month not more than 3 p.p.m. and at least 3 p.p.m. less than the dissolved oxygen.

(4) The stream should be entirely free of preventable organic sludge deposits originating in sewage or industrial wastes and of substances producing tastes in water supplies, or toxic to human or animal populations, or to normal aquatic life.

(5) The alkalinity of the stream under normal flow conditions should average not less than 10 p.p.m. and the pH within a range of 6.0 to 9.0. No free acidity should be present at any time.

Class B

(1) The number of coliform bacteria should average more than 5,000 but less than 20,000 per 100 ml. in any month.

(2) The dissolved oxygen content should average not less than 5 p.p.m. in any month, and not less than 3 p.p.m. on any day.

(3) The 5-Day B.O.D. should average not more than 4 p.p.m. in any month and should not exceed the average dissolved oxygen content on any day.

(4) The stream should be substantially free of preventable organic sludge deposits originating in sewage or industrial wastes, and should be free of substances producing tastes in water supplies, or toxic to human or animal populations or to normal aquatic life.

(5) Same as (5), Class A.

Class C

(1) Numbers of coliform bacteria averaging more than 20,000 per 100 ml. in any month.

(2) Dissolved oxygen content averaging less than 5 p.p.m. in any month, or less than 3 p.p.m. on any day.

(3) 5-Day B.O.D. averaging more than 4 p.p.m. in any month, or exceeding the average D. O. content on any day.

(4) Presence of organic sludge deposits and of substances producing tastes in water supplies, or toxic to human or animal populations, or to normal aquatic life.

(5) Alkalinity averaging lower than 10 p.p.m. and pH beyond the ranges as stated under (5), Class A; free acidity present at any time.

Class AA (Special, for reserved recreational areas).

(1) Number of coliform bacteria not averaging more than 100 per 100 ml. in any month, or longer period, and not exceeding 1,000 per 100 ml. on any day.

(2), (3), (4), and (5). Same as Class A.

Explanatory Remarks.

1. COLIFORM BACTERIA

The limits set for Class A and B waters are based on data obtained from extensive studies of water purification by the Public Health Service.(1) For limiting averages, the month has been taken as the unit of time, as being the shortest period for which a definite indication may be obtained as to whether a given water is suitable for treatment without incurring the risk of undue influence of errors in individual observations. For Class A, the upper limit has been set at a level such that ordinary filtration treatment, with post-chlorination, should be able to produce effluents meeting both primary and secondary requirements of the Treasury Department coliform standard. For Class B, such treatment would not suffice, though if further elaborated, according to the degree of raw water pollution within the range given, it should be able to produce reasonably safe effluents for the greater part of the time. This class

would not be admissible, however, as a source of water supply except under favorable conditions. Class C represents waters which are wholly unfit for sources of water supply, whatever the degree or efficiency of treatment.

2. DISSOLVED OXYGEN

The limiting monthly average of 6.5 p.p.m. for Class A waters corresponds to about 80 per cent of saturation at normal summer temperatures in the Ohio River Basin. A study of the data obtained during the past year from the Ohio River survey indicates that a good stream zone undergoing definite recovery should have an average dissolved oxygen content not falling below 6.5 ppm in any month. To safeguard against temporary lapses in D. O. content which might endanger the proper maintenance of all varieties of native aquatic life, Ellis' minimum of 5 p.p.m.[(2)] has been fixed as a secondary requirement for this Class.

For Class B waters, the limiting average for any month has been set at Ellis' desirable minimum, in order to provide conditions favorable to maintaining a reasonable variety of aquatic life. As a further safeguard, the minimum for any day has been set at 3 p.p.m., which represents the lower limit of oxygen tolerance for all except certain hardy varieties of bottom-feeding fish, such as carp, suckers and bullheads. This would ensure the survival of at least these varieties in the event of any temporary lapse in the reserve oxygen concentration. Class C waters might support in some cases these hardy forms, but in others might be so highly deoxygenated as to support no fish life whatever.

3. 5-Day OXYGEN DEMAND

The requirements for Class A and B are based mainly on a study of the laboratory results from the Ohio River survey, which have indicated that waters

falling into Class A in other respects have shown 5-day B.O.D.'s tending to run definitely below 3 p.p.m. and those in Class B, to run below 4 p.p.m. The latter figure coincides with the upper limit originally fixed by the British Royal Commission[3] for preventing unsatisfactory conditions in streams. The secondary requirement for Class A that the 5-day B.O.D. should also be at least 3 p.p.m. less than the dissolved oxygen content is in accord with Hubbs' specification[4] for satisfactory maintenance of fish life. For Class B waters this requirement could not ordinarily be met, as the required B.O.D. maximum would be inconsistently low.

4. SLUDGE DEPOSITS

The requirements for Classes A and B would practically eliminate organic sludge deposits originating in sewage or industrial wastes, though a very slight leeway in this respect is provided for Class B waters. The purpose of this requirement is to eliminate from stream waters of these two classes any conditions which would interfere with the normal propagation of native varieties of fish. Otherwise no continued maintenance of these species could be ensured, even were all other conditions suitable to maintaining adult fishes. The added requirements of freedom from taste-producing and toxic substances are obviously essential, both from the water supply viewpoint and from that of maintaining aquatic life.

5. ALKALINITY, ACIDITY AND pH

These requirements have been simplified as far as has seemed advisable, in order to avoid undue complications in laboratory examinations of stream waters. The lower limit of alkalinity for Class A and B waters has been fixed tentatively at 10 p.p.m. in order to provide a factor of safety against the undue influence of acidity resulting from mine or steel mill wastes. An effort has been made

to make this limit low enough to cover some good streams which carry a relatively low natural alkalinity, owing to the absence of extensive limestone formations in their watersheds. A better basis for this requirement might be to allow a certain limiting degree of depression in the normal alkalinity of streams, say 20 or 30 per cent, but this would be very difficult to apply because of the uncertainties involved in determining the "normal" alkalinity of streams receiving any amounts of acid wastes.

The limiting pH ranges suggested for both Class A and B waters have been based on the conclusions of Ellis regarding the desirable limits for maintaining fish life in streams, though also involved is the question of providing optimum conditions for water supplies and their purification.

GENERAL REMARKS

The foregoing classification scheme is suggested only as a tentative one, based on the best present knowledge available to the writer as to the main requirements which should be met for good streams, Class A, for intermediate or doubtful streams, Class B, and for definitely poor or intolerably bad streams, Class C. The use of monthly averages in connection with the primary requirements of the scheme needs further examination, as only in the case of the coliform bacterial requirements has any detailed statistical analysis, based on a large volume of data, been made of the frequencies with which variations from the average would be expected during shorter periods. For this reason the requirements for Class A and B waters have been purposely set at relatively high standards of quality in order to provide a factor of safety for lapses during shorter periods.

In applying the results of laboratory observations to showing present existing stream conditions, it may be sufficient for general purposes to consider

the stream waters only on the basis of the primary classification, as a trial application of the scheme to a considerable number of cases has indicated that only in a minor proportion of them will use of the complete requirements result in changing the class designation as obtained by using the primary classification alone. The secondary requirements would have a definite value, however, in deciding particularly important classifications and also eventually in connection with testing the results of corrective measures.

The special class denoted as "AA" is intended to cover requirements for certain reserved streams or stream zones, where the need may exist for stream waters suitable for exceptionally high class recreational facilities, such as bathing and sport fishing. The bacterial requirement stated in this case is patterned after the Winslow-Moxon recommendation(5) for natural bathing waters and the oxygen and other requirements, for maintaining a good variety of native fishes. It hardly appears that any deliberate effort can be made to bring entire streams, where now subject to any considerable pollution, to such a high standard of water quality as is called for by this special class, though in certain relatively uninhabited regions, where conditions favor the reservation of areas devoted wholly or very largely to recreational uses, the application of these requirements would serve a good purpose. It also is quite possible that a by-product of general corrective measures in other areas may be the establishment of limited stream zones meeting the requirements of Class "AA" during that part of the year when these requirements would be most urgent for recreational use of streams.

For a general review of the broader questions concerned with standards of quality for natural stream and lake waters, reference is made to a previous paper(6) on this subject. In preparing the present paper, the writer has drawn

upon a large amount of historical and statistical material used in connection with the previous article. Grateful acknowledgement is made to members of the staff of the Ohio River Pollution Survey for their constructive criticism of the classification scheme herein described.

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(2) Bulletin No. 22, Bureau of Fisheries, U. S. Dept. of Commerce.

(3) British Royal Commission on Sewage Disposal. Eighth and Ninth Reports.

(4) Sewage Works Journal, Vol. 5, pp 1033-40 (1933).

(5) Am. Jour. Pub. Hyg., Vol. 8, No. 3, pp 299-310 (1928)

(6) Sewage Works Journal, Vol. 6, No. 4, pp 721-733(July, 1934).